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Thermal Management Requirements and Properties of IDT PCI Express® Switches

Application Note
AN-534

Notes

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Introduction

An effective thermal management strategy is a critical part of any system design. It is therefore essential that IC vendors provide system designers with pertinent thermal characteristics for their devices. IDT provides basic thermal data for each PCI Express switch in the device data sheet, available from IDT. For most usage scenarios, the information contained in the device data sheet is sufficient to determine the proper thermal management strategy. This application note contains all of the information in the data sheets, as well as additional details on the thermal characteristics of each device.

The purposes of this application note, with respect to each device in the IDT PCI Express switch family, are:

- To present relevant thermal parameters (raw data).
- To provide detailed reference tables, exhibiting PCB (Printed Circuit Board) size vs. number of layers vs. air flow, which customers can use to quickly ascertain heat sink requirements.
- Enable customers to determine the appropriate thermal management strategy for their specific usage scenarios using the raw data.

Important Thermal Parameters and Relationships

This section defines the relevant thermal parameters that are used throughout this application note. Also, equations are introduced in order to show the relationships between the parameters.

Thermal Parameters

Table 1 summarizes key thermal parameters that are used throughout this application note.

Symbol	Parameter	Units	Notes
$T_{J(max)}$	Maximum Junction Temperature	^oC	Specifies the highest allowable junction temperature of the die. Fixed value, given in the device data sheet (125^oC for IDT PCIe switches).
T_A	Maximum Ambient Temperature	^oC	Specifies the highest allowable ambient temperature of the system. 70^oC is the value for commercial temperature range devices.
θ_{JA}	Junction-to-Ambient Thermal Resistance	$^oC/W$	Applicable when no external heat sink is used. Absolute value is specific to each IC package. Effective value is dependent upon PCB parameters and air flow.
θ_{JB}	Junction-to-Board Thermal Resistance	$^oC/W$	Value is specific to each IC package. Assumes that all heat flows through the board.
θ_{JC}	Junction-to-Case Thermal Resistance	$^oC/W$	Applicable when an external heat sink is used. Value is specific to each IC package. Assumes all heat is dissipated through the surface with the heat sink.

Table 1 Relevant Thermal Parameters Defined (Page 1 of 2)

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Symbol	Parameter	Units	Notes
θ_{CS}	Case-to-Sink Thermal Resistance	$^oC/W$	Applicable when an external heat sink is used. Comes from the substance used to adhere the heat sink to the case. Value is approximately $1^oC/W$.
θ_{SA}	Sink-to-Ambient Thermal Resistance	$^oC/W$	Applicable when an external heat sink is used. Value is specific to the heat sink. Dependent upon the amount of air flow in the system. The dimensions of the heat sink should match those of the package.
P	Power Dissipation of the Device	W	Specific to each device and equal to the power consumption of the device as published in the device data sheet.

Table 1 Relevant Thermal Parameters Defined (Page 2 of 2)

Useful Formulas

The junction-to-ambient thermal resistance is a measure of a device's ability to dissipate heat from the die to its surroundings in the absence of a heat sink. The general formula to determine θ_{JA} is:

$$\theta_{JA} = (T_J - T_A)/P \qquad \textit{Equation 1(a)}$$

A variation on Equation 1(a) can be used to find the actual value of T_J in a system, given the effective θ_{JA}, P, and T_A:

$$T_{J(actual)} = T_A + P * \theta_{JA(effective)} \qquad \textit{Equation 1(b)}$$

This value is useful as a comparison to the maximum T_J as a gauge of reliability. Note that the effective θ_{JA} accounts for the necessary PCB characteristics and air flow.

The formula is also useful from a system design perspective. It can be used to determine if a heat sink should be added to the device based on some desired value of T_J:

$$T_{A(allowed)} = T_{J(desired)} - (P * \theta_{JA(effective)}) \qquad \textit{Equation 1(c)}$$

The variations of Equation 1 are used to determine if a heat sink is required, considering all of the relevant parameters. If a heat sink is necessary, then Equation 2 is used to arrive at the necessary value of θ_{SA} for the heat sink.

$$\theta_{SA} = (T_J - T_A)/ P - \theta_{JC} - \theta_{CS} \qquad \textit{Equation 2}$$

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PES8T5 Thermal Considerations

This section describes thermal considerations for the PES8T5 (19mm^2 324-ball BGA package).

PES8T5 Thermal Parameters

The data in Table 2 contains information that is relevant to the thermal performance of the PES8T5.

Symbol	Parameter	Value	Units	Conditions
$T_{J(max)}$	Junction Temperature	125	^oC	Maximum
$T_{A(max)}$	Ambient Temperature	70	^oC	Maximum for commercial-rated products
θ_{JB}	Junction-to-Board Thermal Resistance	11.4	$^oC/W$	19mm^2 324-ball BGA package
θ_{JC}	Junction-to-Case Thermal Resistance	5.1	$^oC/W$	19mm^2 324-ball BGA package
P	Power Dissipation of the Device	2.4	W	Maximum

Table 2 PES8T5 Thermal Specifications, 19x19 mm 324-ball BGA Package

Table 3 provides effective θ_{JA} values based on air flow, number of PCB layers, and PCB size.

8T5		2.7" x 6.6" Low Profile (17.82in)	3.9" x 6.2" Express Module (24.22in)	4.3" x 6.6" Standard Height Half Length (28.42in)	4.3" x 12.2" Standard Height Full Length (52.52in)
Airflow	PCB Layers	θ_{JA} (°C/W)	θ_{JA} (°C/W)	θ_{JA} (°C/W)	θ_{JA} (°C/W)
0	4	23.7	22.3	21.8	21
1	4	15.4	15.2	15.1	15.1
2	4	14	13.8	13.9	13.9
3	4	13.3	13.1	13.2	13.2
0	6	19.9	18.4	18.1	16.6
1	6	12.6	12	11.9	11.7
2	6	11.8	11.2	11	10.9
3	6	11.3	10.7	10.5	10.4
0	10	14.6	13.9	12.9	11.9
1	10	10.6	10.9	10.2	9.9
2	10	9.7	10.1	9.5	9.3
3	10	9.3	9.7	9.1	8.9
0	14	13.8	12.7	12.2	11.1
1	14	10.1	9.8	9.6	9.3
2	14	9.4	9.1	8.9	8.6
3	14	9	8.7	8.5	8.2
0	20	13.1	11.7	11.5	10.3
1	20	9.4	8.9	9	8.5
2	20	8.7	8.2	8.3	7.8
3	20	8.4	7.9	8	7.5

Table 3 PES8T5 Effective Junction-to-Ambient Thermal Resistance Values - $\theta_{JA(effective)}$

Note: The parameter $\theta_{JA(effective)}$ is not the *absolute* thermal resistance for the package as defined by JEDEC (JESD-51). Since it varies with the number of PCB layers, size of the PCB, and airflow, it is the *effective* thermal resistance.

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PES8T5 Heat Sink Requirements

The charts in Figures 1 and 2 specify which scenarios need a heat sink based on common combinations of air flow, PCB size, and number of PCB layers. The PES8T5 does not require a heat sink for most usage scenarios. As the chart in Figure 2 suggests, the introduction of 0.5 m/s of air flow will eliminate the need for a heat sink for any practical board size.

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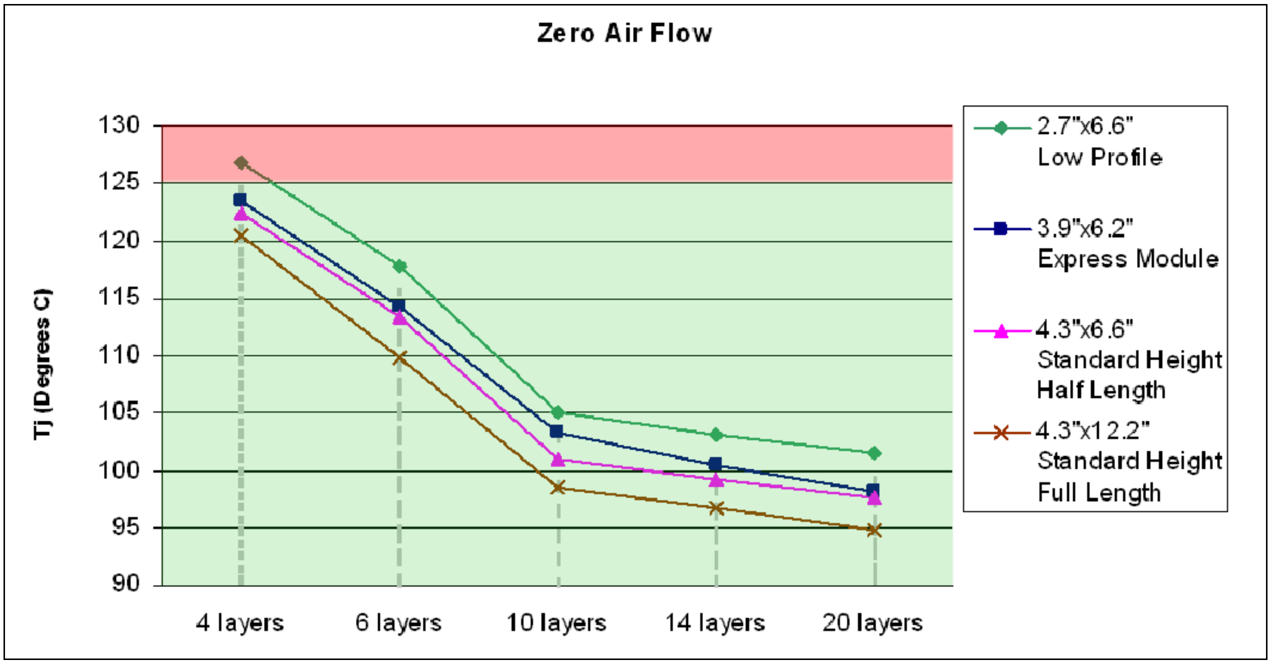

Figure 1 PES8T5 Heat Sink Requirements without Air Flow

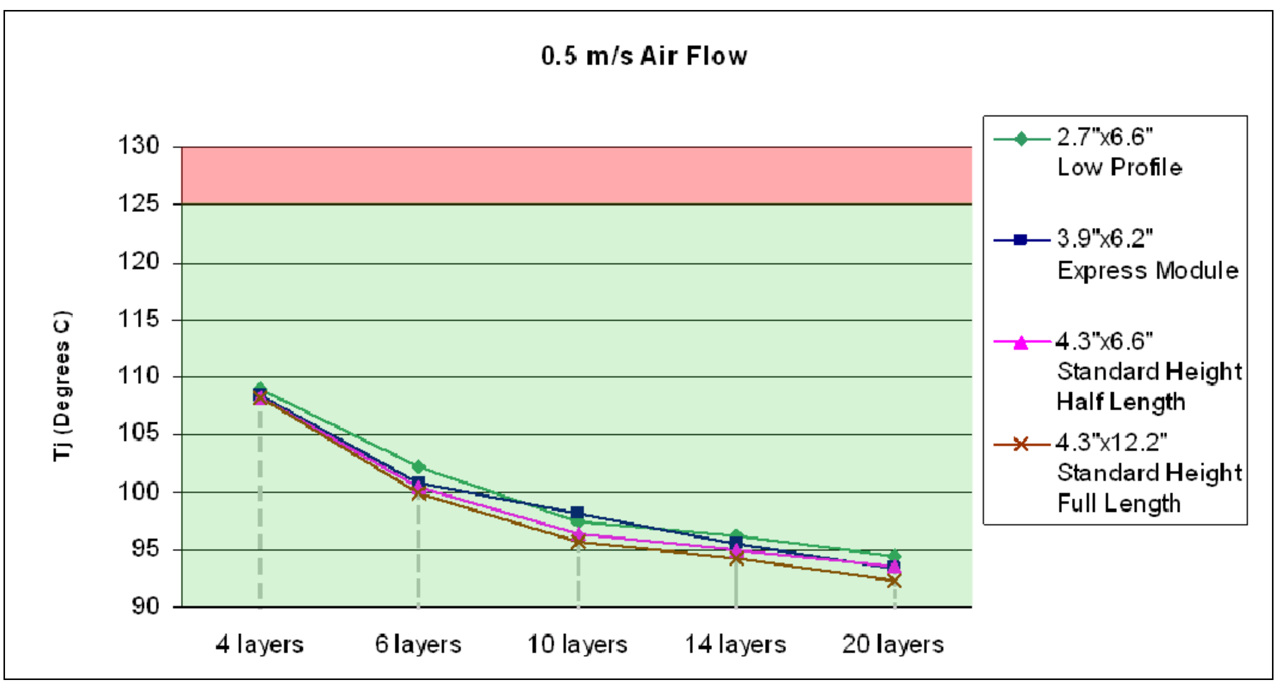

Figure 2 PES8T5 Heat Sink Requirements with Air Flow

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Note: The charts above are based on the values of effective θ_{JA} in Table 3 and assume $T_{J(max)}$=125^{o}C, $T_{A(max)}$=70^{o}C, and PCB temperature equal to T_A.

PES8T5 Heat Sink Calculations

Consider an application that requires the use of a 6-layer, standard height, full length add-in card in a system with no air flow. According to Figure 1, the PES8T5 device does not require a heat sink and we can stop the investigation. But let us suppose that, for the same application, we wish our maximum operating T_J to be 100°C instead of 125°C. We can use Equation 1(a) to determine the highest acceptable junction-to-ambient thermal resistance.

$$\theta_{JA(required)} = (T_J - T_A)/P$$

$$\theta_{JA(required)} = (100^oC - 70^oC)/2.4W$$

$$\theta_{JA(required)} = 12.5^oC/W$$

So, to sustain a maximum operating T_J of *100^{o}C, the value of* $q_{JA(effective)}$ cannot be greater than *12.5^{o}C/W*. From Table 3, the value of $\theta_{JA(effective)}$ is *16.6^{o}C/W. Therefore, a heat sink is required in this case.* In order to select an adequate heat sink, we must calculate its maximum sink-to-ambient thermal resistance value. To do so, we use Equation 2:

$$\theta_{SA(max)} = (T_J - T_A)/ P - \theta_{JC} - \theta_{CS}$$

$$\theta_{SA(max)} = (100^oC - 70^oC)/ 2.4W - 5.1^oC/W - 1.0^oC/W$$

$$\theta_{SA(max)} = 6.4^oC/W$$

This value indicates the need for a 19mm x 19mm heat sink with a sink-to-ambient thermal resistance of *6.4^{o}C/W or less, assuming no air flow.*

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PES12N3A Thermal Considerations

This section describes thermal considerations for the PES12N3A (19mm^2 324-ball BGA package).

PES12N3A Thermal Parameters

The data in Table 4 contains information that is relevant to the thermal performance of the PES12N3A.

Symbol	Parameter	Value	Units	Conditions
$T_{J(max)}$	Junction Temperature	125	^oC	Maximum
$T_{A(max)}$	Ambient Temperature	70	^oC	Maximum for commercial-rated products
θ_{JB}	Junction-to-Board Thermal Resistance	11.4	$^oC/W$	19mm^2 324-ball BGA package
θ_{JC}	Junction-to-Case Thermal Resistance	5.1	$^oC/W$	19mm^2 324-ball BGA package
P	Power Dissipation of the Device	2.6	W	Maximum

Table 4 PES12N3A Thermal Specifications, 19x19 mm 324-ball BGA Package

Table 5 provides effective θ_{JA} values based on air flow, number of PCB layers, and PCB size.

12N3A		2.7" x 6.6" Low Profile (17.82in)	3.9" x 6.2" Express Module (24.22in)	4.3" x 6.6" Standard Height Half Length (28.42in)	4.3" x 12.2" Standard Height Full Length (52.52in)
Airflow	PCB Layers	θ_{JA} ($^oC/W$)	θ_{JA} ($^oC/W$)	θ_{JA} ($^oC/W$)	θ_{JA} ($^oC/W$)
0	4	23.7	22.3	21.8	21
1	4	15.4	15.2	15.1	15.1
2	4	14	13.8	13.9	13.9
3	4	13.3	13.1	13.2	13.2
0	6	19.9	18.4	18.1	16.6
1	6	12.6	12	11.9	11.7
2	6	11.8	11.2	11	10.9
3	6	11.3	10.7	10.5	10.4
0	10	14.6	13.9	12.9	11.9
1	10	10.6	10.9	10.2	9.9
2	10	9.7	10.1	9.5	9.3
3	10	9.3	9.7	9.1	8.9
0	14	13.8	12.7	12.2	11.1
1	14	10.1	9.8	9.6	9.3
2	14	9.4	9.1	8.9	8.6
3	14	9	8.7	8.5	8.2
0	20	13.1	11.7	11.5	10.3
1	20	9.4	8.9	9	8.5
2	20	8.7	8.2	8.3	7.8
3	20	8.4	7.9	8	7.5

Table 5 PES12N3A Effective Junction-to-Ambient Thermal Resistance Values - $\theta_{JA(effective)}$

Note: The parameter $\theta_{JA(effective)}$ is not the *absolute* thermal resistance for the package as defined by JEDEC (JESD-51). Since it varies with the number of PCB layers, size of the PCB, and airflow, it is the *effective* thermal resistance.

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PES12N3A Heat Sink Requirements

The charts in Figures 3 and 4 specify which scenarios need a heat sink based on common combinations of air flow, PCB size, and number of PCB layers. The PES12N3A does not require a heat sink for most usage scenarios. As the chart in Figure 4 suggests, the introduction of 0.5 m/s of air flow will eliminate the need for a heat sink for any practical board size.

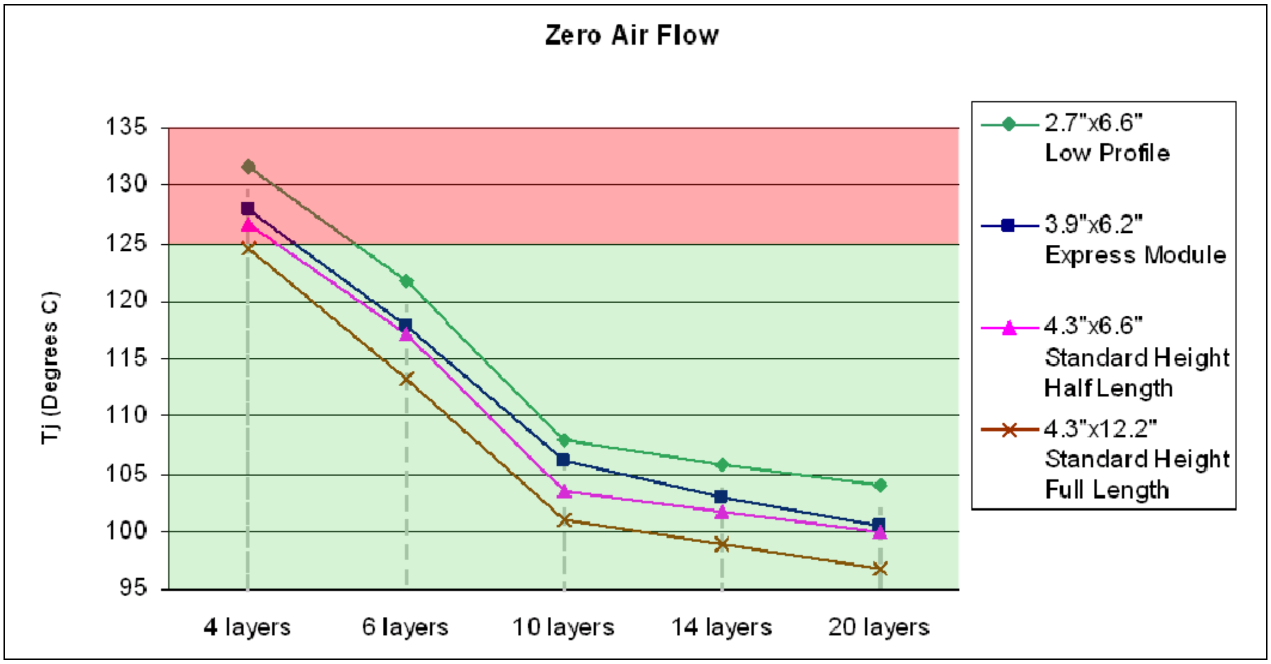

Figure 3 PES12N3A Heat Sink Requirements without Air Flow

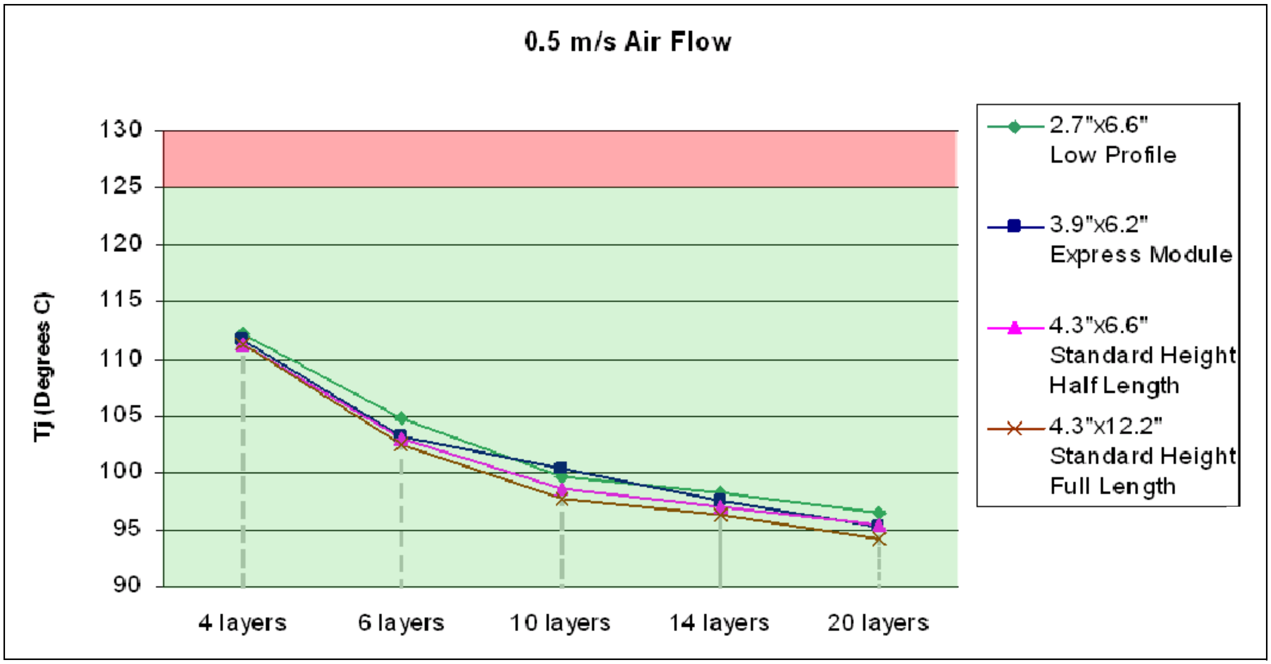

Figure 4 PES12N3A Heat Sink Requirements with Air Flow

Note: The charts above are based on the values of effective θ_{JA} in Table 5 and assume $T_{J(max)}$=125°C, $T_{A(max)}$=70°C, and PCB temperature equal to T_A.

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PES12N3A Heat Sink Calculations

Consider an application that requires the use of a 6-layer, standard height, full length add-in card in a system with no air flow. According to Figure 3, the PES12N3A device does not require a heat sink and we can stop the investigation. But let us suppose that, for the same application, we wish our maximum operating T_J to be 100°C instead of 125°C. We can use Equation 1(a) to determine the highest acceptable junction-to-ambient thermal resistance.

$\theta_{JA(required)} = (T_J - T_A)/P$

$\theta_{JA(required)} = (100^oC - 70^oC)/2.6W$

$\theta_{JA(required)} = 11.54^oC/W$

So, to sustain a maximum operating T_J of *100°C, the value of* $\theta_{JA(effective)}$ cannot be greater than *11.54°C/W*. From Table 5, the value of $\theta_{JA(effective)}$ is *16.6°C/W. Therefore, a heat sink is required in this case.* In order to select an adequate heat sink, we must calculate its maximum sink-to-ambient thermal resistance value. To do so, we use Equation 2:

$\theta_{SA(max)} = (T_J - T_A)/ P - \theta_{JC} - \theta_{CS}$

$\theta_{SA(max)} = (100^oC - 70^oC)/ 2.6W - 5.1^oC/W - 1.0^oC/W$

$\theta_{SA(max)} = 5.44^oC/W$

This value indicates the need for a 19mm x 19mm heat sink with a sink-to-ambient thermal resistance of *5.44°C/W or less, assuming no air flow.*

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PES16T4 Thermal Considerations

This section describes thermal considerations for the PES16T4 ($23mm^2$ 484-ball BGA package).

PES16T4 Thermal Parameters

The data in Table 6 contains information that is relevant to the thermal performance of the PES16T4.

Symbol	Parameter	Value	Units	Conditions
$T_{J(max)}$	Junction Temperature	125	^oC	Maximum
$T_{A(max)}$	Ambient Temperature	70	^oC	Maximum for commercial-rated products
θ_{JB}	Junction-to-Board Thermal Resistance	10.9	$^oC/W$	$23mm^2$ 484-ball BGA package
θ_{JC}	Junction-to-Case Thermal Resistance	5	$^oC/W$	$23mm^2$ 484-ball BGA package
P	Power Dissipation of the Device	2.9	W	Maximum

Table 6 PES16T4 Thermal Specifications, 23x23 mm 484-ball BGA Package

Table 7 provides effective θ_{JA} values based on air flow, number of PCB layers, and PCB size.

16T4		2.7" x 6.6" Low Profile (17.82in)	3.9" x 6.2" Express Module (24.22in)	4.3" x 6.6" Standard Height Half Length (28.42in)	4.3" x 12.2" Standard Height Full Length (52.52in)
Airflow	**PCB Layers**	θ_{JA} (°C/W)	θ_{JA} (°C/W)	θ_{JA} (°C/W)	θ_{JA} (°C/W)
0	**4**	23.3	21.9	21.4	20.6
1	**4**	15.1	14.9	14.8	14.8
2	**4**	13.7	13.5	13.6	13.6
3	**4**	13	12.8	12.9	12.9
0	**6**	19.5	18	17.7	16.4
1	**6**	12.3	11.7	11.6	11.4
2	**6**	11.5	10.9	10.7	10.6
3	**6**	11	10.4	10.2	10.1
0	**10**	14.2	13.5	12.5	11.5
1	**10**	10.3	10.6	9.9	9.6
2	**10**	9.4	9.8	9.2	9
3	**10**	9	9.4	8.8	8.6
0	**14**	13.7	12.6	12.1	11
1	**14**	10	9.7	9.5	9.2
2	**14**	9.3	9	8.8	8.5
3	**14**	8.9	8.6	8.4	8.1
0	**20**	13	11.6	11.4	10.2
1	**20**	9.3	8.8	8.9	8.4
2	**20**	8.6	8.1	8.2	7.7
3	**20**	8.3	7.8	7.9	7.4

Table 7 PES16T4 Effective Junction-to-Ambient Thermal Resistance Values - $\theta_{JA(effective)}$

Note: The parameter $\theta_{JA(effective)}$ is not the *absolute* thermal resistance for the package as defined by JEDEC (JESD-51). Since it varies with the number of PCB layers, size of the PCB, and airflow, it is the *effective* thermal resistance.

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PES16T4 Heat Sink Requirements

The charts in Figures 5 and 6 specify which scenarios need a heat sink based on common combinations of air flow, PCB size, and number of PCB layers. The PES16T4 does not require a heat sink for most usage scenarios. As the chart in Figure 6 suggests, the introduction of 0.5 m/s of air flow will eliminate the need for a heat sink for any practical board size.

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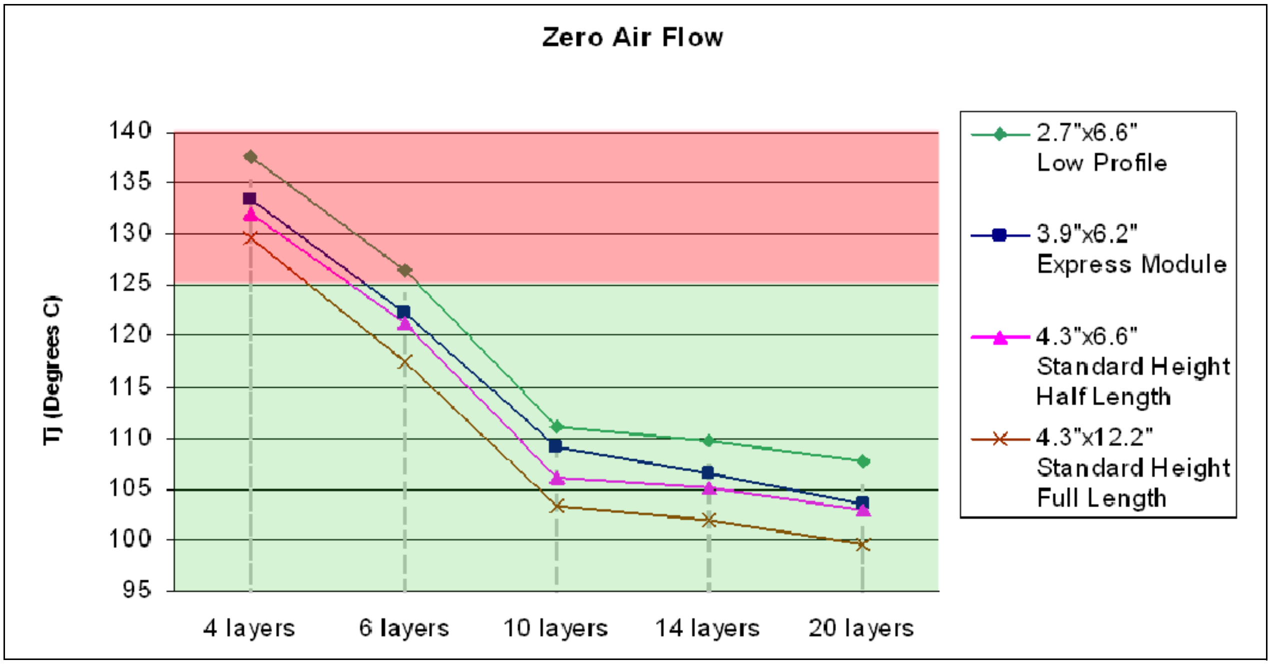

Figure 5 PES16T4 Heat Sink Requirements without Air Flow

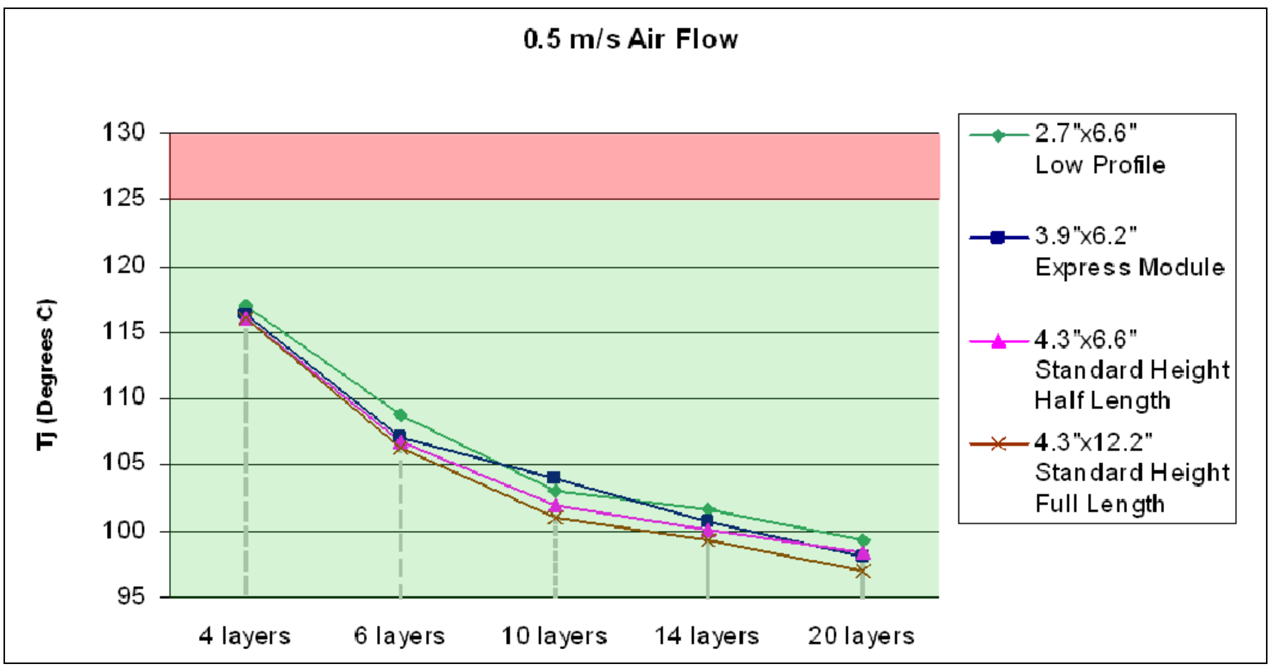

Figure 6 PES16T4 Heat Sink Requirements with Air Flow

Note: The charts above are based on the values of effective θ_{JA} in Table 7 and assume $T_{J(max)}$=125^{o}C, $T_{A(max)}$=70^{o}C, and PCB temperature equal to T_A.

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PES16T4 Heat Sink Calculations

Consider an application that requires the use of a 10-layer, standard height, full length add-in card in a system with no air flow. According to Figure 5, the PES16T4 device does not require a heat sink and we can stop the investigation. But let us suppose that, for the same application, we wish our maximum operating T_J to be 100°C instead of 125°C. We can use Equation 1(a) to determine the highest acceptable junction-to-ambient thermal resistance.

$$\theta_{JA(required)} = (T_J - T_A)/P$$

$$\theta_{JA(required)} = (100^oC - 70^oC)/2.9W$$

$$\theta_{JA(required)} = 10.35^oC/W$$

So, to sustain a maximum operating T_J of *100°C, the value of* $\theta_{JA(effective)}$ cannot be greater than *10.35°C/W*. From Table 7, the value of $\theta_{JA(effective)}$ is *11.5°C/W. Therefore, a heat sink is required in this case.* In order to select an adequate heat sink, we must calculate its maximum sink-to-ambient thermal resistance value. To do so, we use Equation 2:

$$\theta_{SA(max)} = (T_J - T_A)/ P - \theta_{JC} - \theta_{CS}$$

$$\theta_{SA(max)} = (100^oC - 70^oC)/ 2.9W - 5^oC/W - 1.0^oC/W$$

$$\theta_{SA(max)} = 4.34^oC/W$$

This value indicates the need for a 23mm x 23mm heat sink with a sink-to-ambient thermal resistance of *4.34°C/W or less, assuming no air flow.*

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PES16T7 Thermal Considerations

This section describes thermal considerations for the PES16T7 (25mm^2 320-ball BGA package).

PES16T7 Thermal Parameters

The data in Table 8 contains information that is relevant to the thermal performance of the PES16T7.

Symbol	Parameter	Value	Units	Conditions
$T_{J(max)}$	Junction Temperature	125	^oC	Maximum
$T_{A(max)}$	Ambient Temperature	70	^oC	Maximum for commercial-rated products
θ_{JB}	Junction-to-Board Thermal Resistance	7.5	$^oC/W$	25mm^2 320-ball BGA package
θ_{JC}	Junction-to-Case Thermal Resistance	0.7	$^oC/W$	25mm^2 320-ball BGA package
P	Power Dissipation of the Device	3.6	W	Maximum

Table 8 PES16T7 Thermal Specifications, 25x25 mm 320-ball BGA Package

Table 9 provides effective θ_{JA} values based on air flow, number of PCB layers, and PCB size.

16T7		2.7" x 6.6" Low Profile (17.82in)	3.9" x 6.2" Express Module (24.22in)	4.3" x 6.6" Standard Height Half Length (28.42in)	4.3" x 12.2" Standard Height Full Length (52.52in)
Airflow	**PCB Layers**	θ_{JA} ($^oC/W$)	θ_{JA} ($^oC/W$)	θ_{JA} ($^oC/W$)	θ_{JA} ($^oC/W$)
0	**4**	20.5	19	18.5	17.7
1	**4**	12.5	12.3	12.2	12
2	**4**	11.1	10.9	10.8	10.7
3	**4**	10.2	10.1	10.1	10
0	**6**	18.8	16.7	16.5	15.5
1	**6**	11.3	11	10.9	10.7
2	**6**	10.1	9.9	9.9	9.7
3	**6**	9.3	9.2	9.3	9.1
0	**10**	14.7	13	12.8	12
1	**10**	10.6	10.2	10.1	9.9
2	**10**	9.5	9.2	9.1	9
3	**10**	8.7	8.6	8.5	8.4
0	**14**	14.3	12.7	12.6	11.6
1	**14**	10.3	10	9.9	9.7
2	**14**	9.3	9.1	9	8.8
3	**14**	8.5	8.4	8.4	8.3
0	**20**	14	12.5	12.3	11.3
1	**20**	10.1	9.7	9.6	9.4
2	**20**	9.1	8.8	8.7	8.6
3	**20**	8.3	8.2	8.2	8.1

Table 9 PES16T7 Effective Junction-to-Ambient Thermal Resistance Values - $\theta_{JA(effective)}$

Note: The parameter $\theta_{JA(effective)}$ is not the *absolute* thermal resistance for the package as defined by JEDEC (JESD-51). Since it varies with the number of PCB layers, size of the PCB, and airflow, it is the *effective* thermal resistance.

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PES16T7 Heat Sink Requirements

The charts in Figures 7 and 8 specify which scenarios need a heat sink based on common combinations of air flow, PCB size, and number of PCB layers. The PES16T7 does not require a heat sink for most usage scenarios. As the chart in Figure 8 suggests, the introduction of 0.5 m/s of air flow will eliminate the need for a heat sink for any practical board size.

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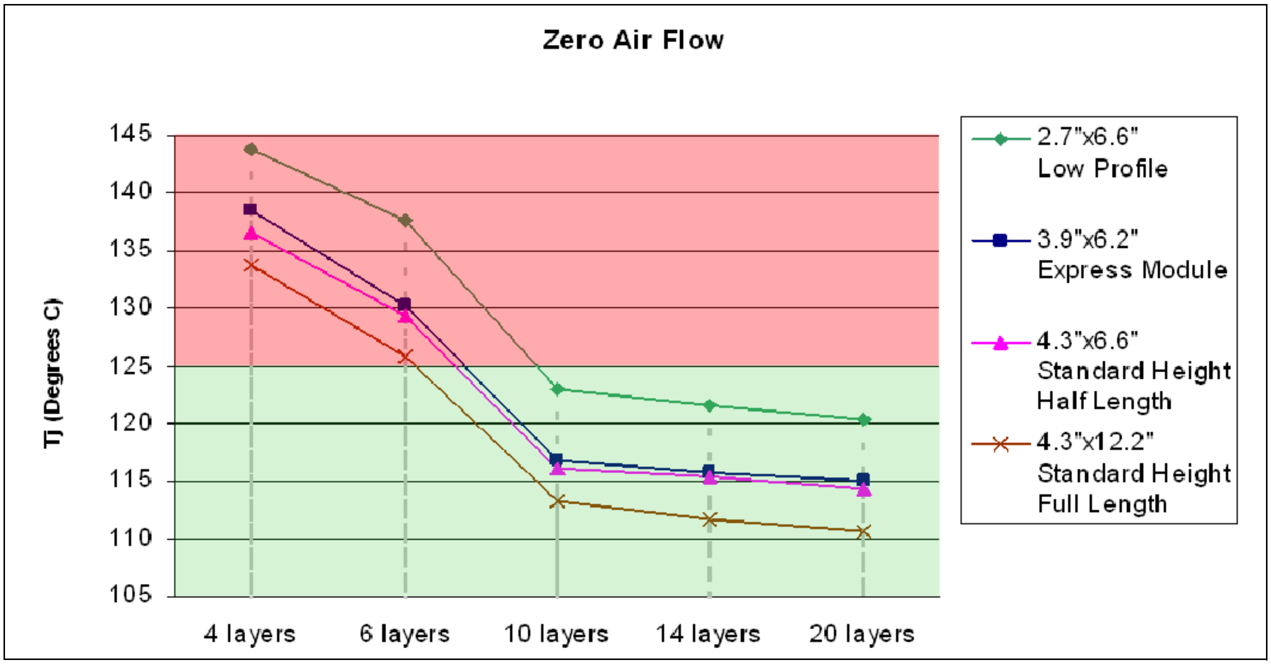

Figure 7 PES16T7 Heat Sink Requirements without Air Flow

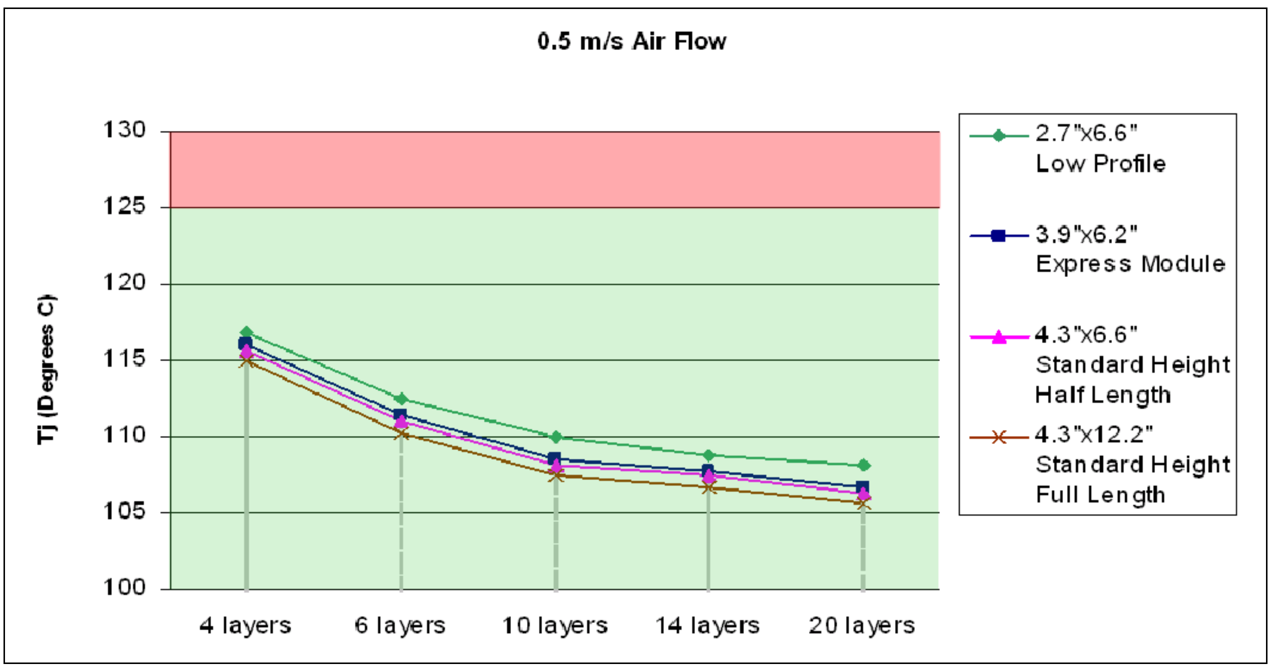

Figure 8 PES16T7 Heat Sink Requirements with Air Flow

Note: The charts above are based on the values of effective θ_{JA} in Table 9 and assume $T_{J(max)}$=125°C, $T_{A(max)}$=70°C, and PCB temperature equal to T_A.

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PES16T7 Heat Sink Calculations

Consider an application that requires the use of a 10-layer, standard height, full length add-in card in a system with no air flow. According to Figure 7, the PES16T7 device does not require a heat sink and we can stop the investigation. But let us suppose that, for the same application, we wish our maximum operating T_J to be 100°C instead of 125°C. We can use Equation 1(a) to determine the highest acceptable junction-to-ambient thermal resistance.

$\theta_{JA(required)} = (T_J - T_A)/P$

$\theta_{JA(required)} = (100^oC - 70^oC)/3.6W$

$\theta_{JA(required)} = 8.33^oC/W$

So, to sustain a maximum operating T_J of *100°C, the value of* $\theta_{JA(effective)}$ cannot be greater than *8.33°C/W*. From Table 9, the value of $\theta_{JA(effective)}$ is *12°C/W. Therefore, a heat sink is required in this case.*

In order to select an adequate heat sink, we must calculate its maximum sink-to-ambient thermal resistance value. To do so, we use Equation 2:

$\theta_{SA(max)} = (T_J - T_A)/ P - \theta_{JC} - \theta_{CS}$

$\theta_{SA(max)} = (100^oC - 70^oC)/ 3.6W - 0.7^oC/W - 1.0^oC/W$

$\theta_{SA(max)} = 6.63^oC/W$

This value indicates the need for a 25mm x 25mm heat sink with a sink-to-ambient thermal resistance of *6.63°C/W or less, assuming no air flow.*

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PES24N3A Thermal Considerations

This section describes thermal considerations for the PES24N3A (27mm^2 420-ball BGA package).

PES24N3A Thermal Parameters

The data in Table 10 contains information that is relevant to the thermal performance of the PES24N3A.

Symbol	Parameter	Value	Units	Conditions
$T_{J(max)}$	Junction Temperature	125	^oC	Maximum
$T_{A(max)}$	Ambient Temperature	70	^oC	Maximum for commercial-rated products
θ_{JB}	Junction-to-Board Thermal Resistance	6.8	$^oC/W$	27mm^2 420-ball BGA package
θ_{JC}	Junction-to-Case Thermal Resistance	0.7	$^oC/W$	27mm^2 420-ball BGA package
P	Power Dissipation of the Device	3.9	W	Maximum

Table 10 PES24N3A Thermal Specifications, 27x27 mm 420-ball BGA Package

Table 11 provides effective θ_{JA} values based on air flow, number of PCB layers, and PCB size.

24N3A		2.7" x 6.6" Low Profile (17.82in)	3.9" x 6.2" Express Module (24.22in)	4.3" x 6.6" Standard Height Half Length (28.42in)	4.3" x 12.2" Standard Height Full Length (52.52in)
Airflow	**PCB Layers**	θ_{JA} (°C/W)	θ_{JA} (°C/W)	θ_{JA} (°C/W)	θ_{JA} (°C/W)
0	**4**	19.1	17.6	17.1	16.3
1	**4**	11.1	10.9	10.8	10.6
2	**4**	9.7	9.5	9.4	9.3
3	**4**	8.8	8.75	8.7	8.6
0	**6**	17.4	15.3	15.1	14.1
1	**6**	9.9	9.6	9.5	9.3
2	**6**	8.7	8.55	8.5	8.3
3	**6**	7.9	7.85	7.9	7.7
0	**10**	13.3	11.6	11.4	10.6
1	**10**	9.2	8.8	8.7	8.5
2	**10**	8.1	7.8	7.7	7.6
3	**10**	7.3	7.2	7.15	7
0	**14**	12.9	11.3	11.2	10.2
1	**14**	8.9	8.6	8.5	8.3
2	**14**	7.9	7.7	7.6	7.4
3	**14**	7.1	7.05	7	6.9
0	**20**	12.6	11.1	10.9	9.9
1	**20**	8.7	8.3	8.2	8
2	**20**	7.7	7.4	7.3	7.2
3	**20**	6.9	6.83	6.8	6.7

Table 11 PES24N3A Effective Junction-to-Ambient Thermal Resistance Values - $\theta_{JA(effective)}$

Note: The parameter $\theta_{JA(effective)}$ is not the *absolute* thermal resistance for the package as defined by JEDEC (JESD-51). Since it varies with the number of PCB layers, size of the PCB, and airflow, it is the *effective* thermal resistance.

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PES24N3A Heat Sink Requirements

The charts in Figures 9 and 10 specify which scenarios need a heat sink based on common combinations of air flow, PCB size, and number of PCB layers. The PES24N3A does not require a heat sink for most usage scenarios. As the chart in Figure 10 suggests, the introduction of 0.5 m/s of air flow will eliminate the need for a heat sink for any practical board size.

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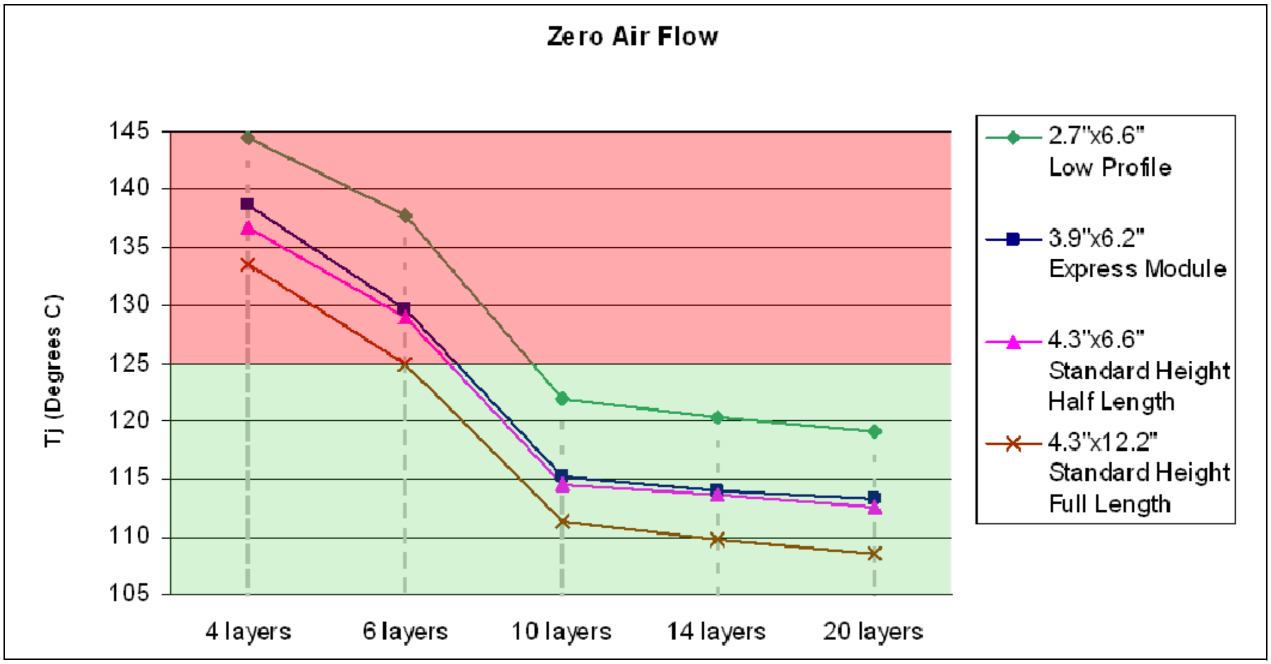

Figure 9 PES24N3A Heat Sink Requirements without Air Flow

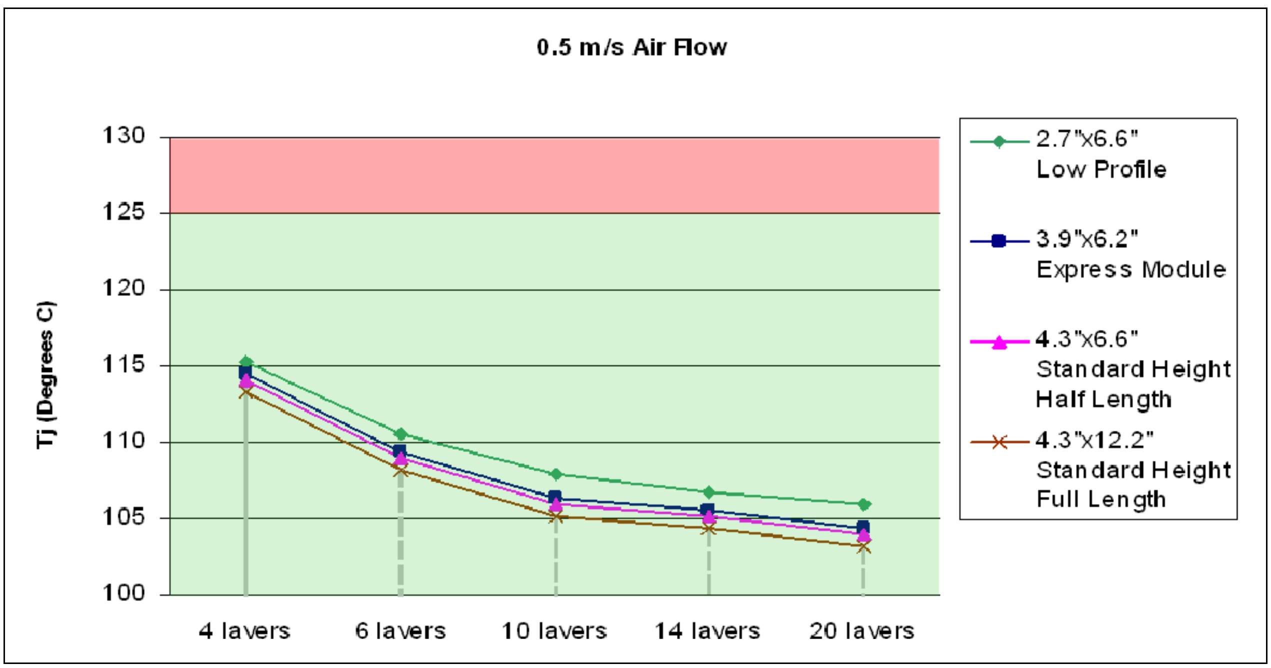

Figure 10 PES24N3A Heat Sink Requirements with Air Flow

Note: The charts above are based on the values of effective θ_{JA} in Table 11 and assume $T_{J(max)}$=125^{o}C, $T_{A(max)}$=70^{o}C, and PCB temperature equal to T_A.

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PES24N3A Heat Sink Calculations

Consider an application that requires the use of a 10-layer, standard height, full length add-in card in a system with no air flow. According to Figure 9, the PES24N3A device does not require a heat sink and we can stop the investigation. But let us suppose that, for the same application, we wish our maximum operating T_J to be 100°C instead of 125°C. We can use Equation 1(a) to determine the highest acceptable junction-to-ambient thermal resistance.

$$\theta_{JA(required)} = (T_J - T_A)/P$$

$$\theta_{JA(required)} = (100^oC - 70^oC)/3.9W$$

$$\theta_{JA(required)} = 7.7^oC/W$$

So, to sustain a maximum operating T_J of *100°C, the value of* $\theta_{JA(effective)}$ cannot be greater than *7.7°C/W*. From Table 11, the value of $\theta_{JA(effective)}$ is *10.6°C/W. Therefore, a heat sink is required in this case.* In order to select an adequate heat sink, we must calculate its maximum sink-to-ambient thermal resistance value. To do so, we use Equation 2:

$$\theta_{SA(max)} = (T_J - T_A)/ P - \theta_{JC} - \theta_{CS}$$

$$\theta_{SA(max)} = (100^oC - 70^oC)/ 3.9W - 0.7^oC/W - 1.0^oC/W$$

$$\theta_{SA(max)} = 6.0^oC/W$$

This value indicates the need for a 27mm x 27mm heat sink with a sink-to-ambient thermal resistance of *6.0°C/W or less, assuming no air flow.*

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PES24T6 Thermal Considerations

This section describes thermal considerations for the PES24T6 ($27mm^2$ 420-ball BGA package).

PES24T6 Thermal Parameters

The data in Table 12 contains information that is relevant to the thermal performance of the PES24T6.

Symbol	Parameter	Value	Units	Conditions
$T_{J(max)}$	Junction Temperature	125	^oC	Maximum
$T_{A(max)}$	Ambient Temperature	70	^oC	Maximum for commercial-rated products
θ_{JB}	Junction-to-Board Thermal Resistance	6.8	$^oC/W$	$27mm^2$ 420-ball BGA package
θ_{JC}	Junction-to-Case Thermal Resistance	0.7	$^oC/W$	$27mm^2$ 420-ball BGA package
P	Power Dissipation of the Device	3.8	W	Maximum

Table 12 PES24T6 Thermal Specifications, 27x27 mm 420-ball BGA Package

Table 13 provides effective θ_{JA} values based on air flow, number of PCB layers, and PCB size.

24T6		2.7" x 6.6" Low Profile (17.82in)	3.9" x 6.2" Express Module (24.22in)	4.3" x 6.6" Standard Height Half Length (28.42in)	4.3" x 12.2" Standard Height Full Length (52.52in)
Airflow	PCB Layers	θ_{JA} (°C/W)	θ_{JA} (°C/W)	θ_{JA} (°C/W)	θ_{JA} (°C/W)
0	4	19.1	17.6	17.1	16.3
1	4	11.1	10.9	10.8	10.6
2	4	9.7	9.5	9.4	9.3
3	4	8.8	8.75	8.7	8.6
0	6	17.4	15.3	15.1	14.1
1	6	9.9	9.6	9.5	9.3
2	6	8.7	8.55	8.5	8.3
3	6	7.9	7.85	7.9	7.7
0	10	13.3	11.6	11.4	10.6
1	10	9.2	8.8	8.7	8.5
2	10	8.1	7.8	7.7	7.6
3	10	7.3	7.2	7.15	7
0	14	12.9	11.3	11.2	10.2
1	14	8.9	8.6	8.5	8.3
2	14	7.9	7.7	7.6	7.4
3	14	7.1	7.05	7	6.9
0	20	12.6	11.1	10.9	9.9
1	20	8.7	8.3	8.2	8
2	20	7.7	7.4	7.3	7.2
3	20	6.9	6.83	6.8	6.7

Table 13 PES24T6 Effective Junction-to-Ambient Thermal Resistance Values - $\theta_{JA(effective)}$

Note: The parameter $\theta_{JA(effective)}$ is not the *absolute* thermal resistance for the package as defined by JEDEC (JESD-51). Since it varies with the number of PCB layers, size of the PCB, and airflow, it is the *effective* thermal resistance.

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PES24T6 Heat Sink Requirements

The charts in Figures 11 and 12 specify which scenarios need a heat sink based on common combinations of air flow, PCB size, and number of PCB layers. The PES24T6 does not require a heat sink for most usage scenarios. As the chart in Figure 12 suggests, the introduction of 0.5 m/s of air flow will eliminate the need for a heat sink for any practical board size.

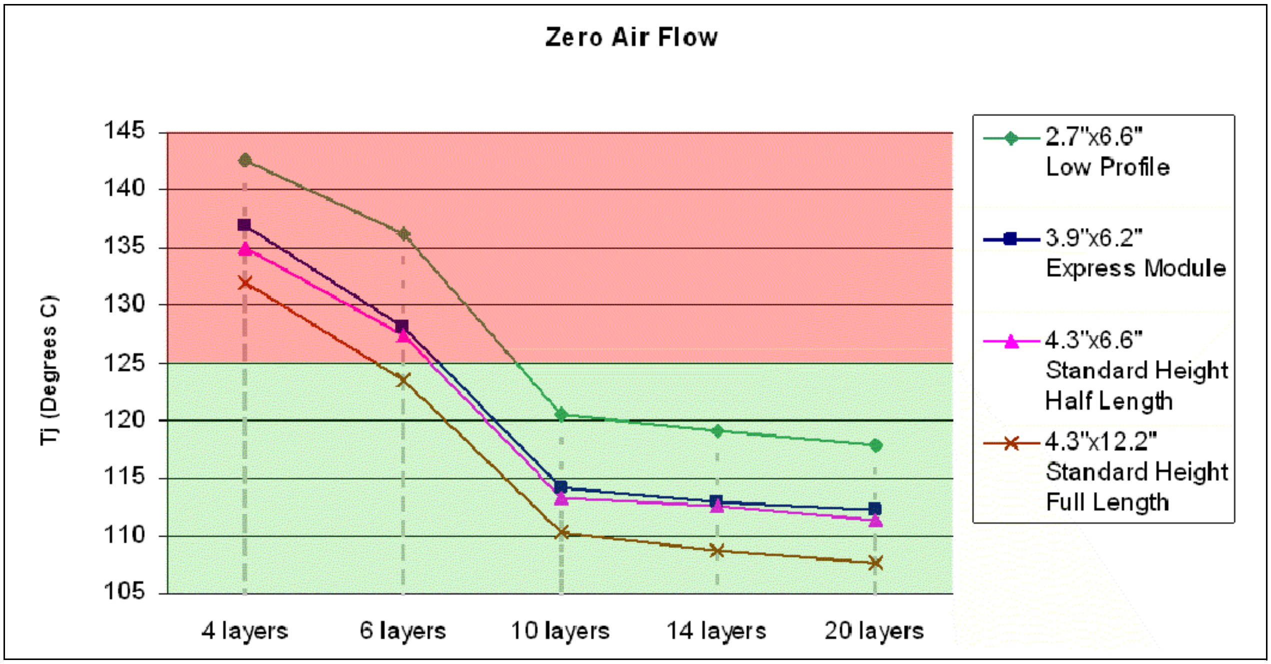

Figure 11 PES24T6 Heat Sink Requirements without Air Flow

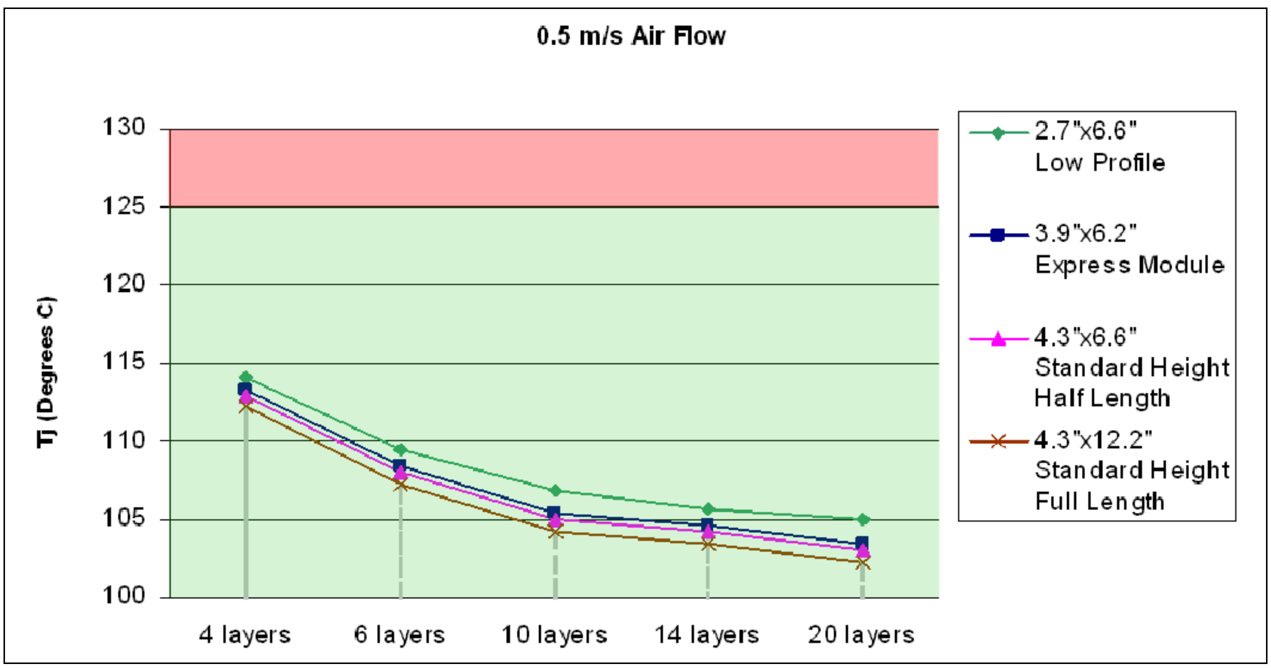

Figure 12 PES24T6 Heat Sink Requirements with Air Flow

Note: The charts above are based on the values of effective θ_{JA} in Table 13 and assume $T_{J(max)}$=125°C, $T_{A(max)}$=70°C, and PCB temperature equal to T_A.

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PES24T6 Heat Sink Calculations

Consider an application that requires the use of a 10-layer, standard height, full length add-in card in a system with no air flow. According to Figure 11, the PES24T6 device does not require a heat sink and we can stop the investigation. But let us suppose that, for the same application, we wish our maximum operating T_J to be 100°C instead of 125°C. We can use Equation 1(a) to determine the highest acceptable junction-to-ambient thermal resistance.

$$\theta_{JA(required)} = (T_J - T_A)/P$$

$$\theta_{JA(required)} = (100^oC - 70^oC)/3.8W$$

$$\theta_{JA(required)} = 7.9^oC/W$$

So, to sustain a maximum operating T_J of *100°C, the value of* $\theta_{JA(effective)}$ cannot be greater than *7.9°C/W*. From Table 13, the value of $\theta_{JA(effective)}$ is *10.6°C/W. Therefore, a heat sink is required in this case.* In order to select an adequate heat sink, we must calculate its maximum sink-to-ambient thermal resistance value. To do so, we use Equation 2:

$$\theta_{SA(max)} = (T_J - T_A)/ P - \theta_{JC} - \theta_{CS}$$

$$\theta_{SA(max)} = (100^oC - 70^oC)/ 3.8W - 0.7^oC/W - 1.0^oC/W$$

$$\theta_{SA(max)} = 6.2^oC/W$$

This value indicates the need for a 27mm x 27mm heat sink with a sink-to-ambient thermal resistance of *6.2°C/W or less, assuming no air flow.*

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PES32T8 Thermal Considerations

This section describes thermal considerations for the PES32T8 (31mm^2 500-ball BGA package).

PES32T8 Thermal Parameters

The data in Table 14 contains information that is relevant to the thermal performance of the PES32T8.

Symbol	Parameter	Value	Units	Conditions
$T_{J(max)}$	Junction Temperature	125	^oC	Maximum
$T_{A(max)}$	Ambient Temperature	70	^oC	Maximum for commercial-rated products
θ_{JB}	Junction-to-Board Thermal Resistance	6.0	$^oC/W$	31mm^2 500-ball BGA package
θ_{JC}	Junction-to-Case Thermal Resistance	0.7	$^oC/W$	31mm^2 500-ball BGA package
P	Power Dissipation of the Device	5.0	W	Maximum

Table 14 PES32T8 Thermal Specifications, 31x31 mm 500-ball BGA Package

Table 15 provides effective θ_{JA} values based on air flow, number of PCB layers, and PCB size.

32T8		2.7" x 6.6" Low Profile (17.82in)	3.9" x 6.2" Express Module (24.22in)	4.3" x 6.6" Standard Height Half Length (28.42in)	4.3" x 12.2" Standard Height Full Length (52.52in)
Airflow	**PCB Layers**	θ_{JA} ($^oC/W$)	θ_{JA} ($^oC/W$)	θ_{JA} ($^oC/W$)	θ_{JA} ($^oC/W$)
0	**4**	17.8	16.3	15.8	15
1	**4**	10.2	10	9.9	9.7
2	**4**	8.9	8.7	8.6	8.5
3	**4**	8	7.95	7.9	7.8
0	**6**	16.1	14	13.8	12.8
1	**6**	9	8.7	8.6	8.4
2	**6**	7.9	7.75	7.7	7.5
3	**6**	7.1	7.05	7.1	6.9
0	**10**	12	10.3	10.1	9.3
1	**10**	8.3	7.9	7.8	7.6
2	**10**	7.3	7	6.9	6.8
3	**10**	6.5	6.4	6.35	6.2
0	**14**	11.6	10	9.9	8.9
1	**14**	8	7.7	7.6	7.4
2	**14**	7.1	6.9	6.8	6.6
3	**14**	6.3	6.25	6.2	6.1
0	**20**	11.3	9.8	9.6	8.6
1	**20**	7.8	7.4	7.3	7.1
2	**20**	6.9	6.6	6.5	6.4
3	**20**	6.1	6.03	6	5.9

Table 15 PES32T8 Effective Junction-to-Ambient Thermal Resistance Values - $\theta_{JA(effective)}$

Note: The parameter $\theta_{JA(effective)}$ is not the *absolute* thermal resistance for the package as defined by JEDEC (JESD-51). Since it varies with the number of PCB layers, size of the PCB, and airflow, it is the *effective* thermal resistance.

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PES32T8 Heat Sink Requirements

The charts in Figures 13 and 14 specify which scenarios need a heat sink based on common combinations of air flow, PCB size, and number of PCB layers. The PES32T8 does not require a heat sink for most usage scenarios. As the chart in Figure 14 suggests, the introduction of 1 m/s of air flow will eliminate the need for a heat sink for all but the smallest board sizes.

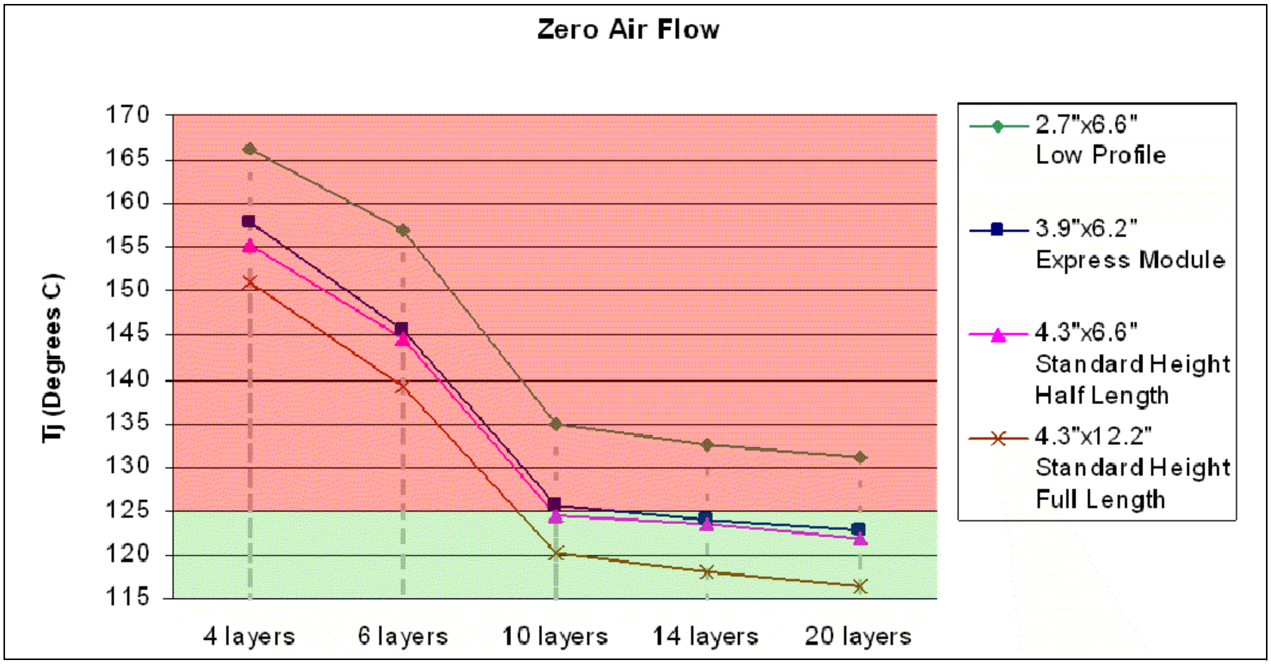

Figure 13 PES32T8 Heat Sink Requirements without Air Flow

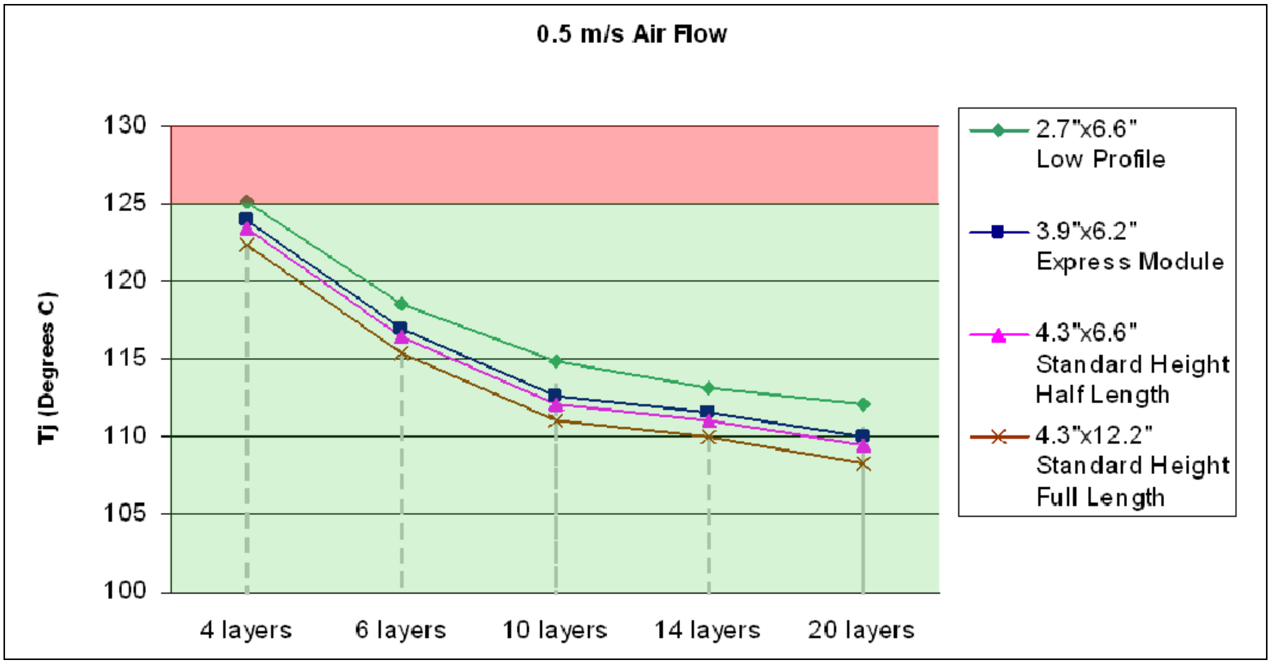

Figure 14 PES32T8 Heat Sink Requirements with Air Flow

Note: The charts above are based on the values of effective θ_{JA} in Table 15 and assume $T_{J(max)}=125^oC$, $T_{A(max)}=70^oC$, and PCB temperature equal to T_A.

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PES32T8 Heat Sink Calculations

Consider an application that requires the use of a 10-layer, standard height, full length add-in card in a system with no air flow. According to Figure 13, the PES32T8 device does not require a heat sink and we can stop the investigation. But let us suppose that, for the same application, we wish our maximum operating T_J to be 100°C instead of 125°C. We can use Equation 1(a) to determine the highest acceptable junction-to-ambient thermal resistance.

$$\theta_{JA(required)} = (T_J - T_A)/P$$

$$\theta_{JA(required)} = (100^oC - 70^oC)/5.0W$$

$$\theta_{JA(required)} = 6^oC/W$$

So, to sustain a maximum operating T_J of *100°C, the value of* $\theta_{JA(effective)}$ cannot be greater than *6°C/W*. From Table 15, the value of $\theta_{JA(effective)}$ is *9.3°C/W. Therefore, a heat sink is required in this case.* In order to select an adequate heat sink, we must calculate its maximum sink-to-ambient thermal resistance value. To do so, we use Equation 2:

$$\theta_{SA(max)} = (T_J - T_A)/ P - \theta_{JC} - \theta_{CS}$$

$$\theta_{SA(max)} = (100^oC - 70^oC)/ 5.0W - 0.7^oC/W - 1.0^oC/W$$

$$\theta_{SA(max)} = 4.3^oC/W$$

This value indicates the need for a 31mm x 31mm heat sink with a sink-to-ambient thermal resistance of *4.3°C/W or less, assuming no air flow.*

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